FIFTH TECHNICAL PROGRESS REPORT
For the Period April, May, June 1966

DEVELOPMENT OF TECHNOLOGICAL CONCEPTS LEADING
TO THE BENEFICIAL USE OF LUNAR MAGMA PRODUCTS

Contract NAS 7-358

Principal Investigator, E. Azmon, Ph.D.

ACTIVITIES LAST QUARTER

During this quarter, 107 new determinations have been made of the solid-liquid phase transformations of igneous rocks from temperatures of 300°C to 2000°C. This brings the total number of determinations to date to 488, or 1.63 determinations per working day. These numbers reflect the cost and efficiency of performing the experiments but have no bearing on the comprehensiveness of the post experiment analysis or on the number of significant data points and evaluations. The five students who are assisting us on a part time basis on this contract have demonstrated unusual maturity and efficiency. Two of these students are doctoral candidates at the University of Southern California (USC); two are doctoral candidates at the University of California in Los Angeles (UCLA), and one is an Engineering candidate at the Northrop Institute of Technology. These students were selected on the basis of their potential ability to help us and their potential participation in future space activities. We hope that at least one of the group will choose to stay with us when he receives his Ph.D.

With the assistance noted above, we have accelerated the rate of analyses but left the number of experiments at the same level. This was possible since the perfection of the experimental techniques has resulted in a higher ratio of successful experiments, and since we were fortunate to have no major breakdown in the equipment. We are maintaining a backlog of partly analyzed experiments to keep the research going should a major breakdown occur.

NEW DATA

The following informal presentation and interpretations of the data are, in some cases quite preliminary, and will therefore need to be substantiated with more data before they can be considered as proven facts.

1. Basalt

Petrographic analyses of tholeiitic basalts were run to determine the changes in percentages of glass, and crystals after the specimens had been subjected to various temperature-pressure combinations for durations of 5 minutes. The results of these data are plotted in Figure 1 showing the percent glass divided by the corresponding temperature versus the pressure. The temperature plot shows no definite pattern whereas the pressure plot shows a definite trend. This indicates that pressure is the dominant factor controlling the percent glass in the samples in the pressure temperature range covered by the experiments.

Plotting the data as percent crystals versus the ratio of temperature to pressure all the points fall along the sides of a triangle (Figure 2). It is interesting to compare this figure with Figure 3 and search for correlations between physical properties measured as seismological data and the petrological identities measured as genetic states in the rocks at high temperatures and pressures. It is convenient to use T/P rather than specific volume as a common denominator for comparison of petrological and seismological properties because both T and P can be easily measured in the laboratory on a routine basis.

In attempting to relate features which are observed in the laboratory to those which are found in the natural environment, basalt samples taken at various depths from the Malpar's Flow of east-central New Mexico were examined. The examination indicated that:

1. more glass occurred near and at the margins of the flow; e.g. top, sides, and bottom.

2. no significant mineralogical changes occurred in the traverse.

3. vesiculation studies indicated that the vesicles occur in greater number near the top of the flow than the sides and bottom.

4. vesicles are more ellipsoidal at the top and bottom of the flow.

5. the largest and most spherical vesicles occur about midway between the top and bottom of the flow.

6. the greatest concentration of zeolites also occur where the largest vesicles are found.

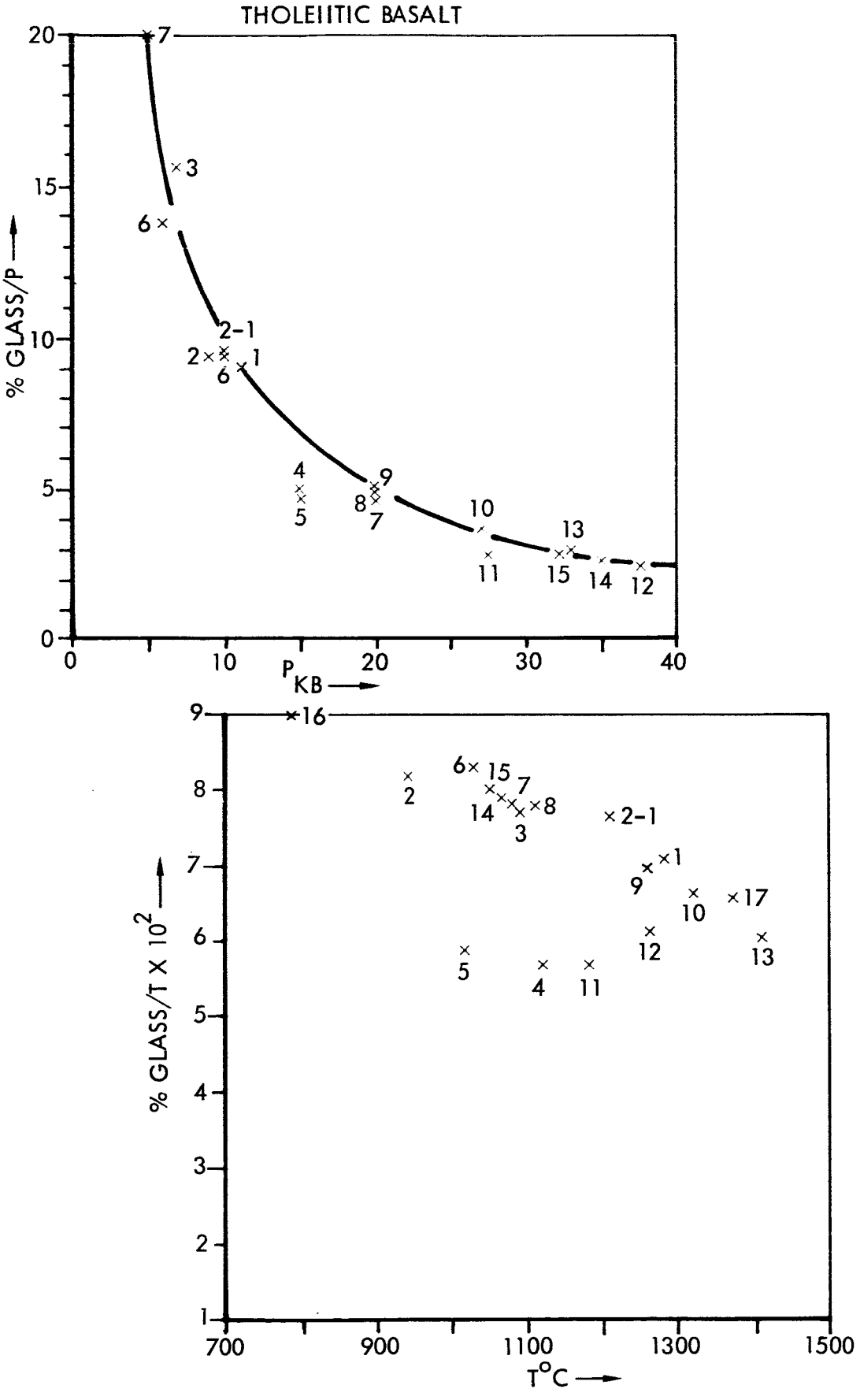

FIGURE 1. PRESSURE AND TEMPERATURE RELATIONS TO PERCENT GLASS

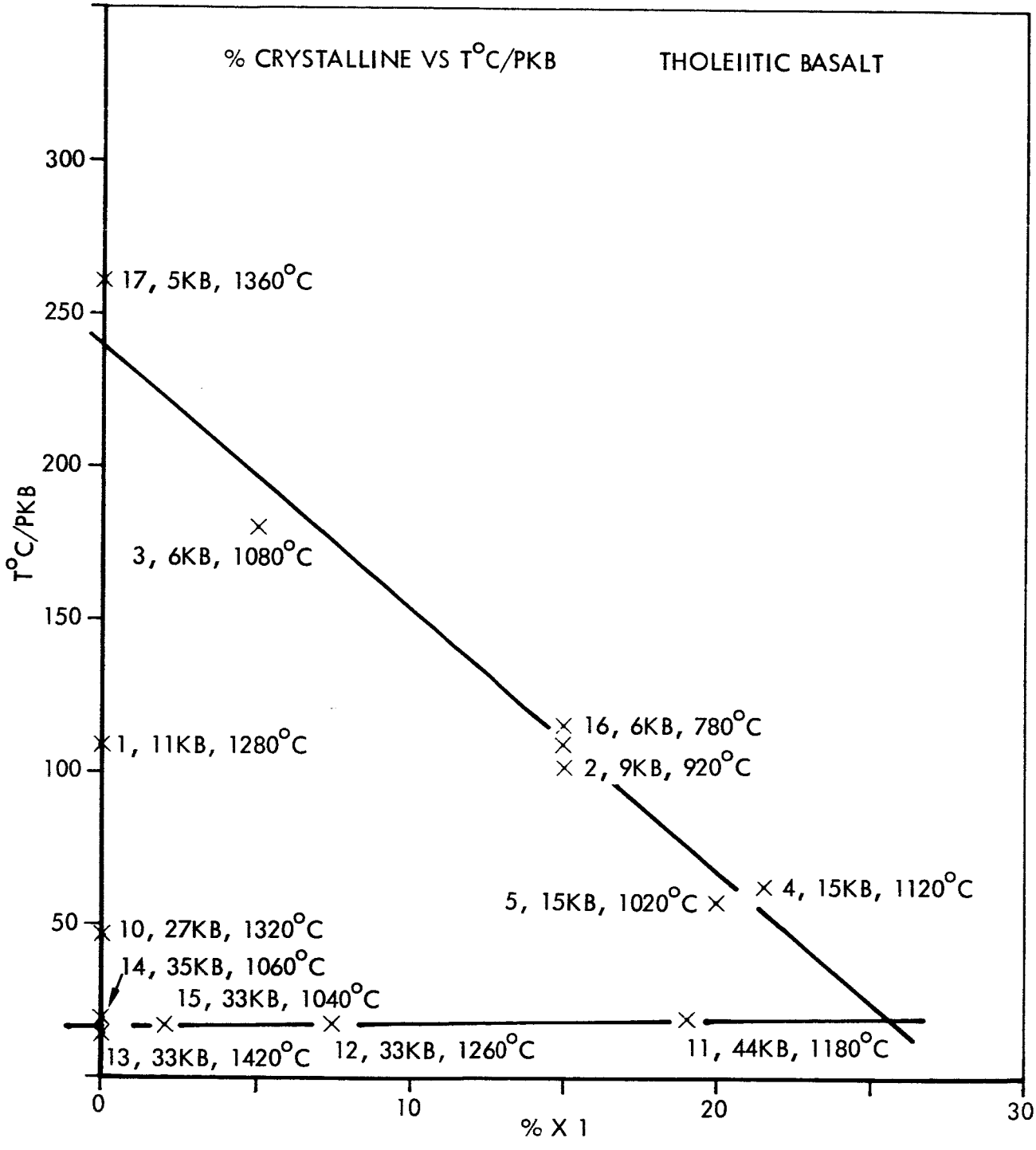

FIGURE 2. TEMPERATURE OVER PRESSURE RELATION TO PERCENT CRYSTALS

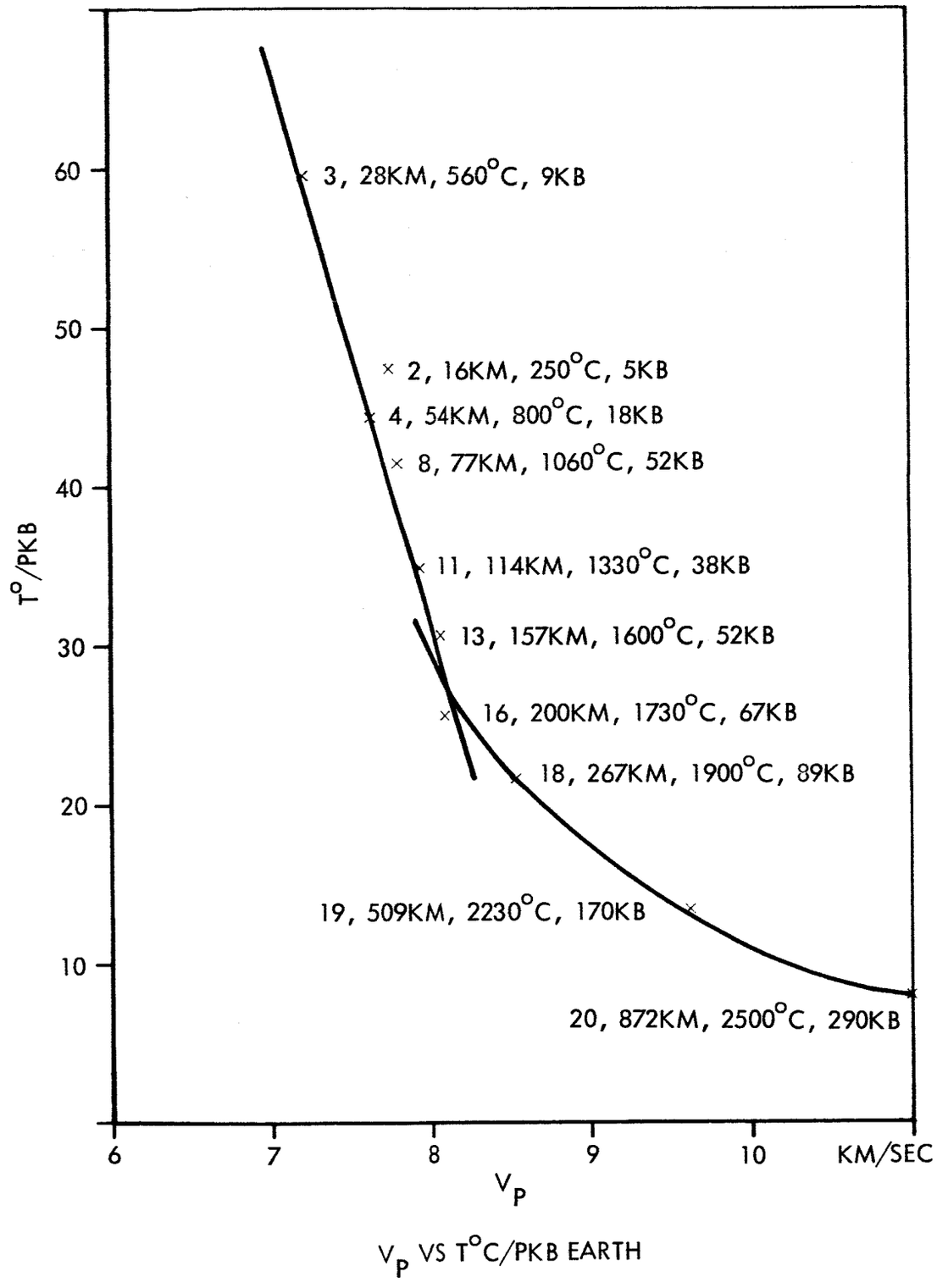

FIGURE 3. TEMPERATURE OVER PRESSURE RELATION TO VELOCITY OF P WAVES

7. flow lineation only gave a 2-dimensional orientation and the source direction could not be picked.

8. imbrication of Pc laths were inconclusive as to source direction of the flow.

9. mega-features such as bent vesicles and streaming indicated directional vector; however these only indicated the last flow direction.

The evaluation of the Malpar's basalt in terms of the genetic states which existed during its genesis must wait till we complete the laboratory experiments on the equivalent rocks.

2. Granodiorite

Petrographic and X-ray examinations of granodiorite were run to determine phase transformations, including changes in percentages of glass and crystals after the specimens had been modified by various temperature pressure combinations for durations of 1, 5 and 10 minutes. The original phases of plagioclase feldspar and quartz mostly disappear near 35 kilobars and new minerals, coesite and jadite, appear. It seems that the amount of glass increases with the time maintained at temperature, but no drop in apparent melting temperature was observed. A drop in the "50 percent melt" curve (Figure 4) between 30 and 35 kilobars corresponds with the transformation of the quartz and feldspar into coesite and jadites. Figure 5 which displays the percent glass as function of pressure at 1200°C, shows an abrupt rise in the amount of glass between 30 and 35 kilobars. The correlation of the high pressure transformation to the percent glass is obvious.

As to the formation of coesite (mentioned in the last report) more experiments will be necessary to evaluate the significance of its high rate of formation.

3. Serpentine

Study of the serpentine phases under pressure at temperatures from 300°C to 1500°C continued, using Differential Thermal Analysis techniques to determine changes in situ, and petrographic and X-ray diffraction techniques for examination of the samples after quenching. Four phases were defined:

1. serpentine - antigorite
2. olivine - forsterite
3. pyroxene - enstatite
4. glass

The antigorite to forsterite transformation is obviously a loss of water which evaporates into the boron nitride and talc sleeves.

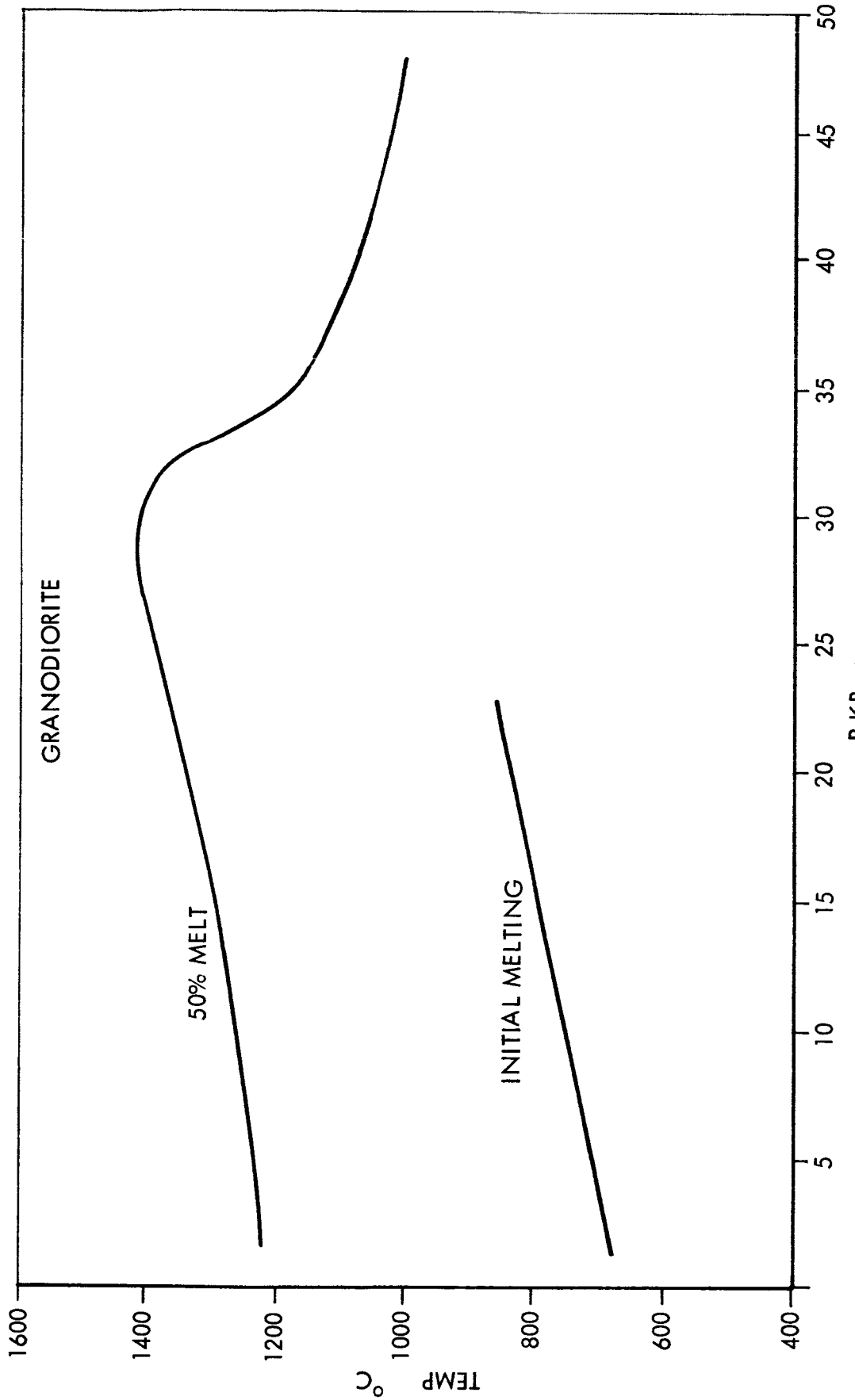

FIGURE 4. MELTING OF GRANODIORITE FROM THE SIERRA NEVADA BATHOLITH AS FUNCTION OF PRESSURE AND TEMPERATURE

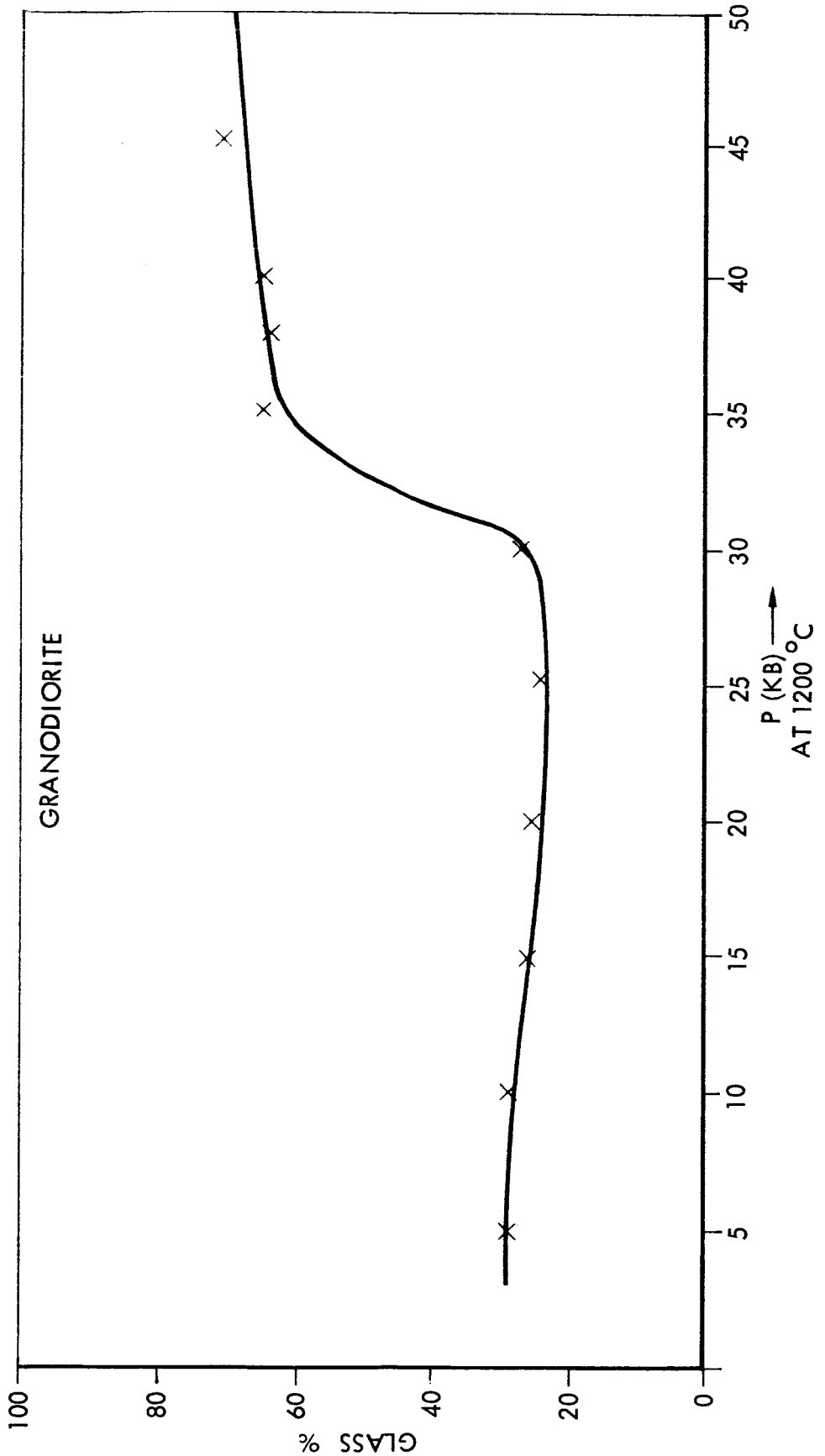

FIGURE 5. PERCENT GLASS AS FUNCTION OF PRESSURE AT 1200°C

The forsterite to pyroxene transformation involves loss of metal oxide, however, the final glass should regain the composition of the forsterite. Two sets of experiments were conducted so far, one at 5 minutes stay at temperature and one at 15 minutes stay. The data will be plotted as soon as the analysis is finished.

Two minor problems were encountered during the examination and are being evaluated: 1) at around 900°C some iron and magnesium migrates along the platinum thermocouple wires; 2) several X-ray diffraction patterns show evidence of a magnesium borate which is a definite evidence that the boron nitride capsule occasionally reacts with the iron-magnesium silicate.

4. Olivine Series

Synthetic samples of forsterite 100, 80, 60, 40, 20, fayalite 100 have been prepared for examination of the shifting of the eutectic temperature and the effect of Al_2O_3 traces on the fructionation of iron magnesium silicate magma. The preliminary experimentation with pure forsterite ($2MgO\ SiO_2$) at pressures of 20 kilobars and temperature of 2000°C were kept at conditions for about 10 minute each. It was found necessary to modify the sample-capsule arrangement to make it easier to locate the sample after a very high temperature run. These were first attempts to stay at such a high temperature for longer than one second and the results are encouraging. It appears that the pistons and core survived the experiments with minimum degradation.

PLANNED ACTIVITY FOR NEXT QUARTER

We will concentrate our efforts during this quarter primarily on the analyses of natural serpentine and synthetic oliving and proceed with the comparison of these analyses with more analysis of natural dunite. This plan is based on the estimate that 1) the very high temperature experiments tie up the equipment for longer time per experiment due to reconditioning required after each run, 2) the next series of time dependence runs will tie up the equipment for longer time per experiment, 3) we have to accomodate vacation schedules during this quarter. The one atmosphere runs will continue at the same rate in attempt to tie in the high pressure with the data available on behavior of rocks at raised temperatures.

E. Azmon

E. Azmon, Ph.D.
Principal Investigator

J. W. Moyer, Director
Physical Sciences